Internal Government Studies

1995

Reports and Presentations

Study Name: **Passive Microwave Polarimetry for Ocean Wind Field(Velocity)**

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INTERNAL GOVERNMENT STUDIES - FY 1995
Passive Microwave Polarimetry for Ocean Wind Field(Speed & Direction)

Presentation/Paper Title	Author(s)	Date
"Validation and Study of Aircraft Polarimetric Radiometer Data, IGS Final Presentation	P. Chang, P. Gaiser G. Poe, Li Li	28 SEPT 95
"Passive Polarimetry Internal Concept Study- Final Report"	P. Chang, P. Gaiser G. Poe, Li Li	28 SEPT 95
"ICS Interim Meeting Presentation to the IPO, Passive Polarimetry-Airborne Validation"	P. Gaiser, G. Poe P. Chang	30 JUNE 95
'Tolarimetric Wind Validation Monthly Progress Report- MAY 95"	P. Gaiser	20 JUNE 95

Validation and Study of Aircraft Polarimetric Radiometer Data

Internal Concept Study for the NPOESS Integrated Program Office

Internal Concept Study Final Results Review
28 September 1995

Paul Chang and Li Li, NOAA/NESDIS/Office of Research and Applications
Peter Gaiser and Gene Poe, NRL Remote Sensing Division

Ocean Wind Remote Sensing Background

- Historically, Scatterometer Required for Wind Direction Sensing
  - SASS, ERS-1 AMI, NSCAT
- SSM/I Operationally Measures Wind Speed
- Recent Work Reveals Possibility of Measuring Direction Passively
- Scatterometer Pros and Cons
  - Retrieves Direction, Better Performance in High Water Vapor and Liquid Water, "Cleaner" Data
  - Power Hungry, Narrow Swath
- Radiometer Pros and Cons
  - Large Swath, Lower Cost, Low Power
  - No Direction, Higher Sensitivity to Atmosphere (SSM/I λ's)
- Potential of Retrieving Wind Direction with Radiometry Offers Large Payoff for Small Investment

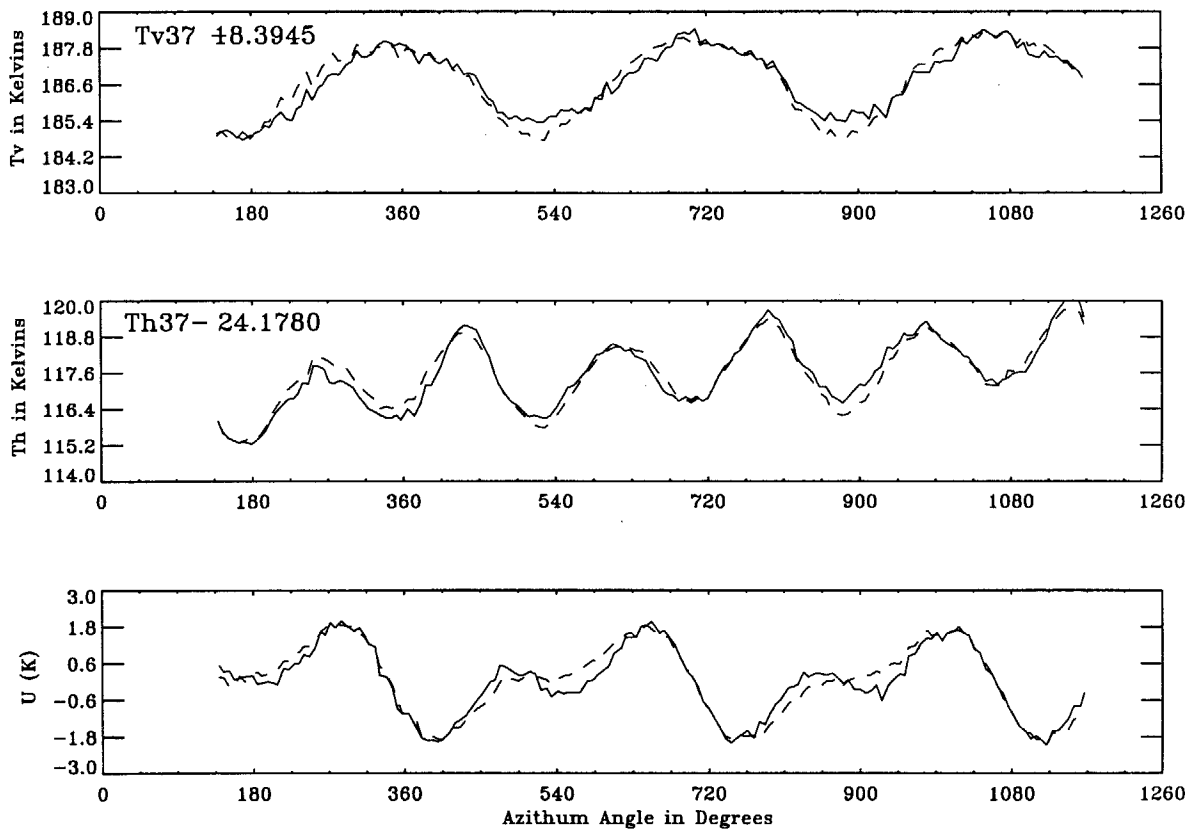
Accomplishments

- Performed Data Quality Control on 1994 WINDRAD Data Set
- Collected Collaborative Data
  - NDBC Buoys, SSM/I, ERS-1
- Performed Analysis on Fourier Harmonics
- Developed Several Neural Network Retrieval Algorithms
  - One-Look/Dual Frequency (Polarimetric)
  - One-Look/Single Frequency (Polarimetric)
  - Two-Look/Dual Frequency (Dual Polarization)
  - Two-Look/Single Frequency (Dual Polarization)
- Making Preliminary Recommendations

1994 WINDRAD Experiment

- 19 and 37 GHz Radiometers - Tv, Th, U
- Circle Flights Around NDBC Buoys
- 45, 55, and 65 Degree Incidence Angles
- 2 - 10 m/s Wind Speeds
- Clear Sky and Cloudy Conditions
- Data Set Limitations
  - Small Data Set, No High Winds, NoWater Vapor Data, Hourly Reported Buoy Winds

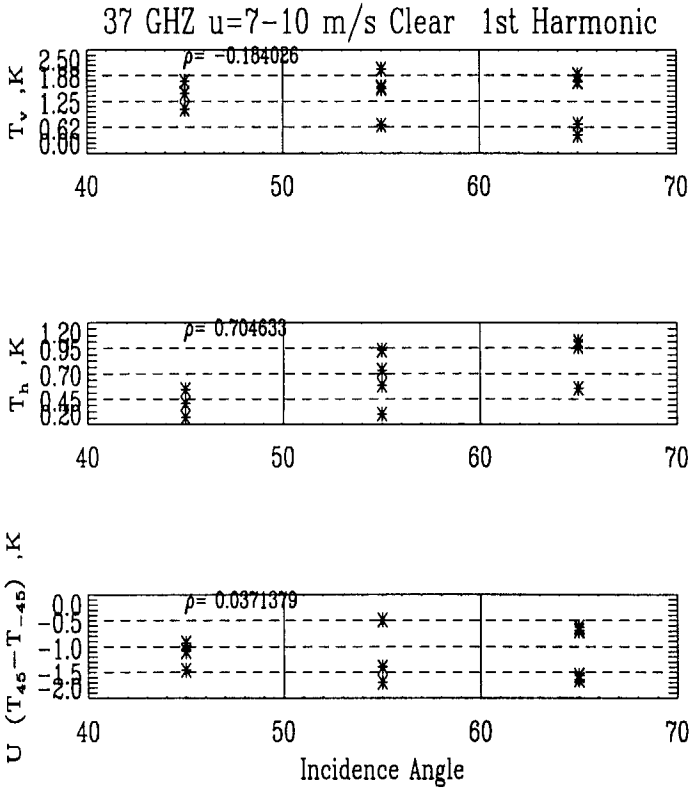
Sample Raw Data Set

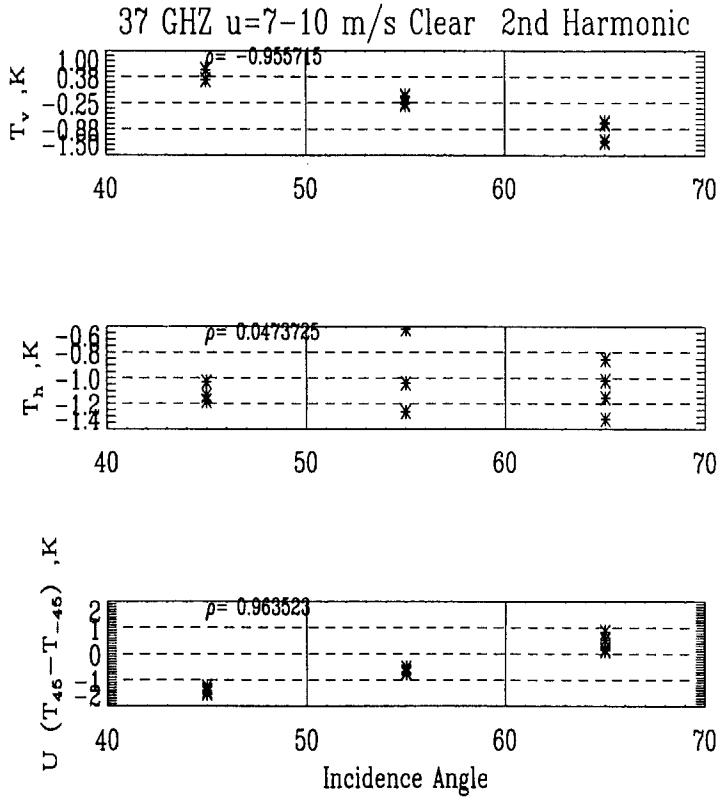


Analysis of Fourier Harmonics

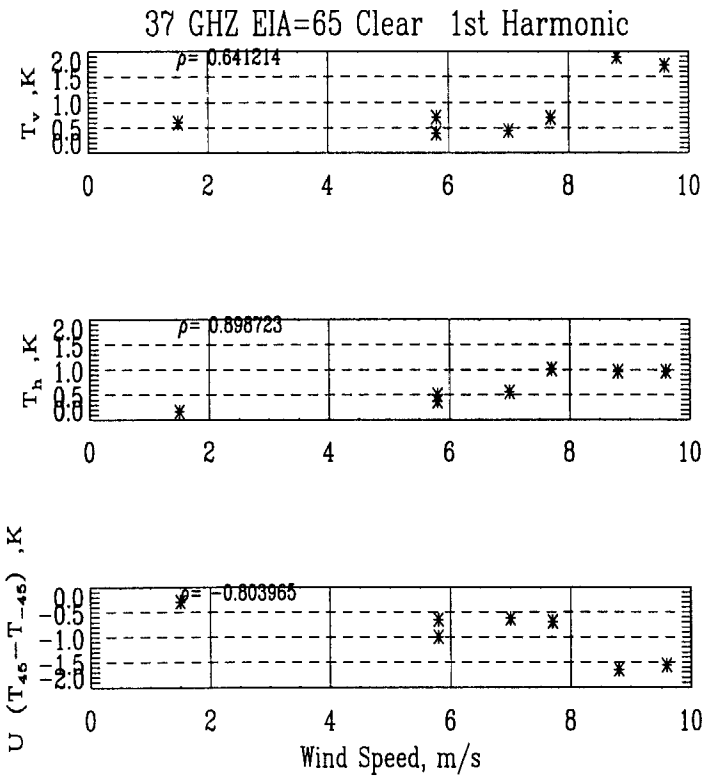
- Calculate the DC-Term and the First Two Harmonics
- Examining the Sensitivity of Harmonics to Buoy Wind Vector, Incidence Angle and Other Parameters
- Useful Tool for Studying Behavior and Consistency of Data
- Reveals Some Inconsistencies in Data — Useful in Data Quality Control
- Demonstrates the Importance of Removing Atmospheric Effects

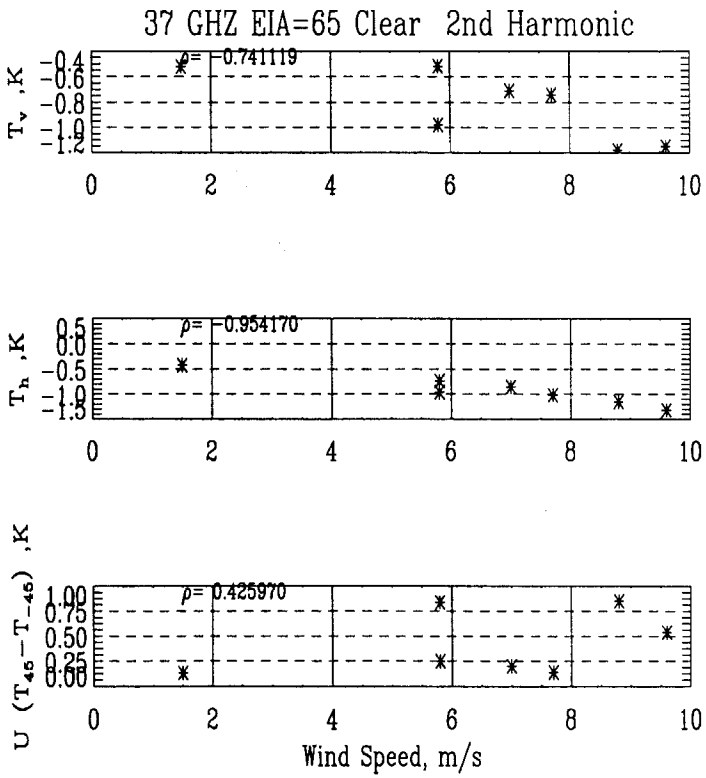
Fourier Analysis
Harmonics Variation with Incidence Angle



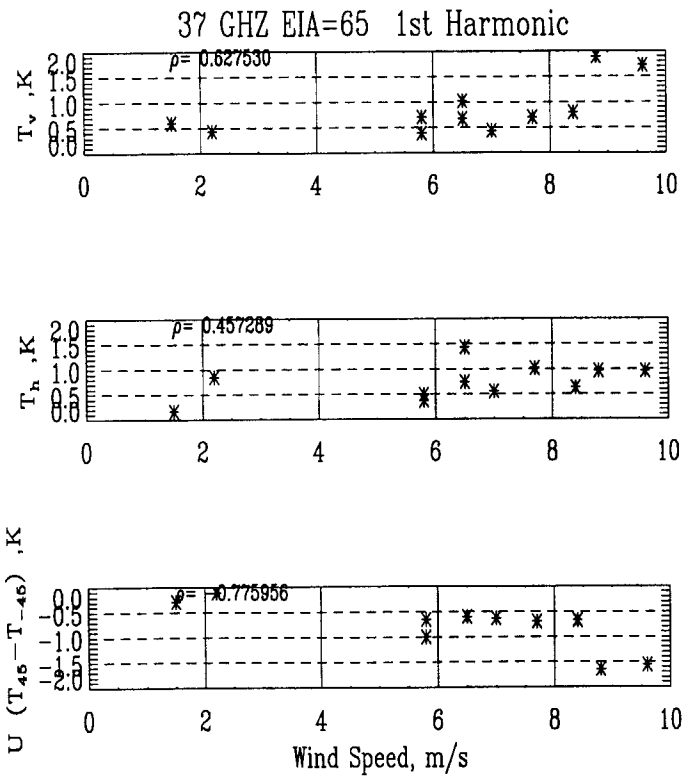


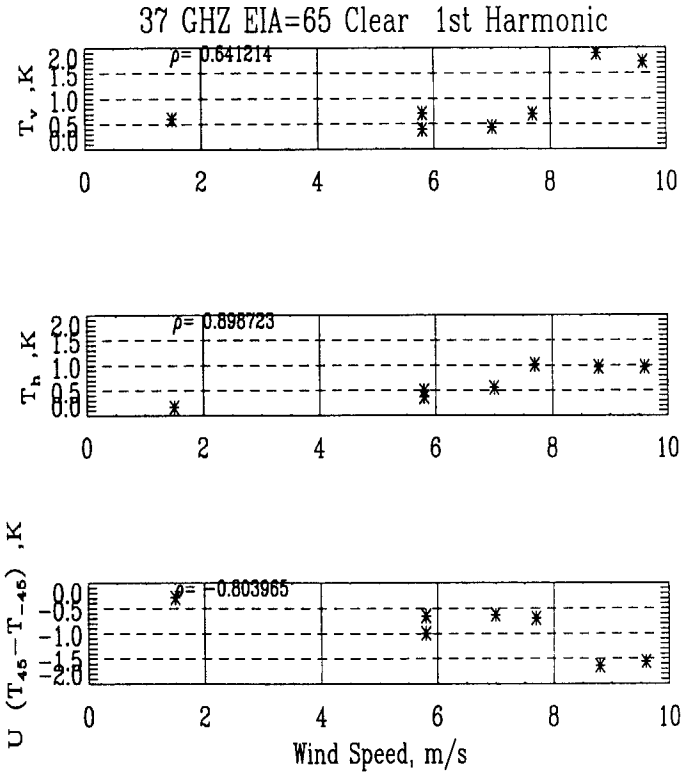
Fourier Analysis
Harmonics Sensitivity to Wind Speed





Fourier Analysis
Effects of Clouds





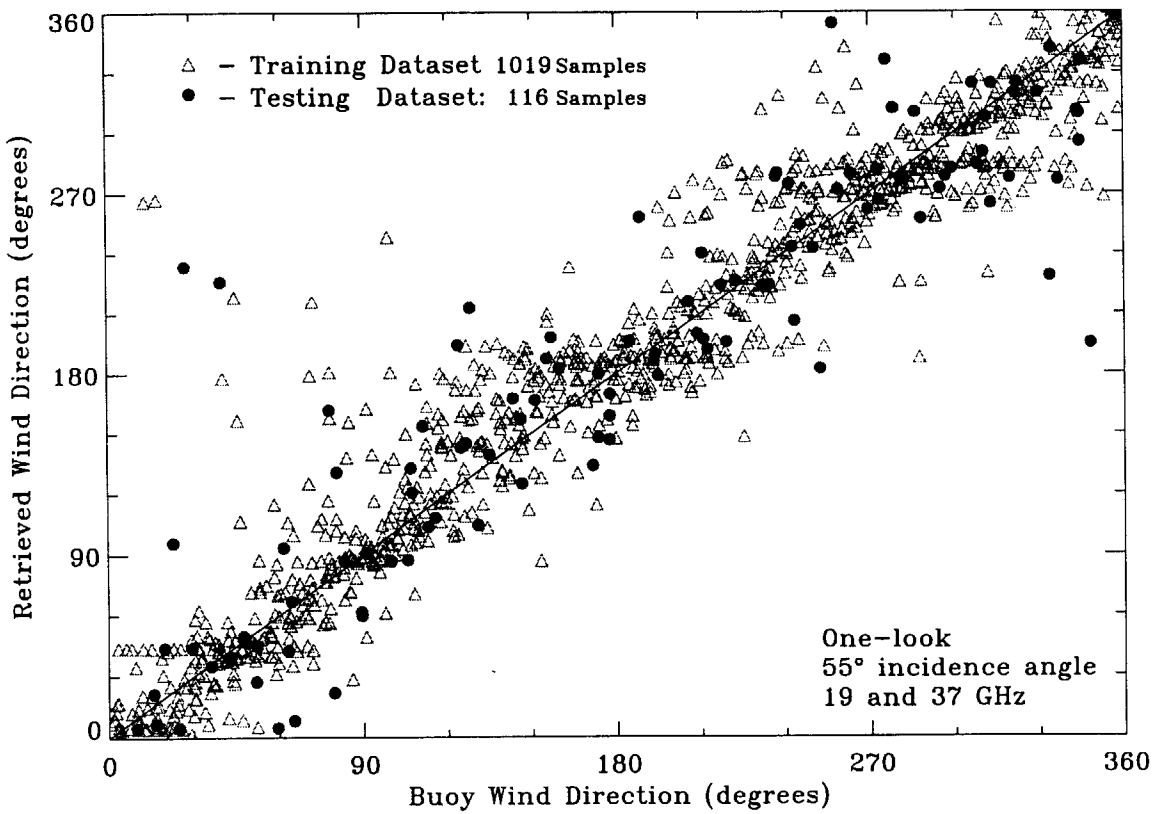
Fourier Analysis

- All Three Incidence Angles Have Useful Harmonics
  - T_h Second Harmonic Strong Across All Angles
  - U and T_v Second Harmonics Vary Strongly With Incidence Angle
- Present Data Set Does Not Indicate a Superior Incidence Angle
- Harmonics Highly Correlated with Wind Speed
- The Presence of Clouds Attenuates Surface Signature and Decreases Strength of Harmonics and Correlations
- Stresses the Importance of 1995 Flight Data, Which Includes Data at 10 and 22 GHz, As Well as 19 and 37 GHz

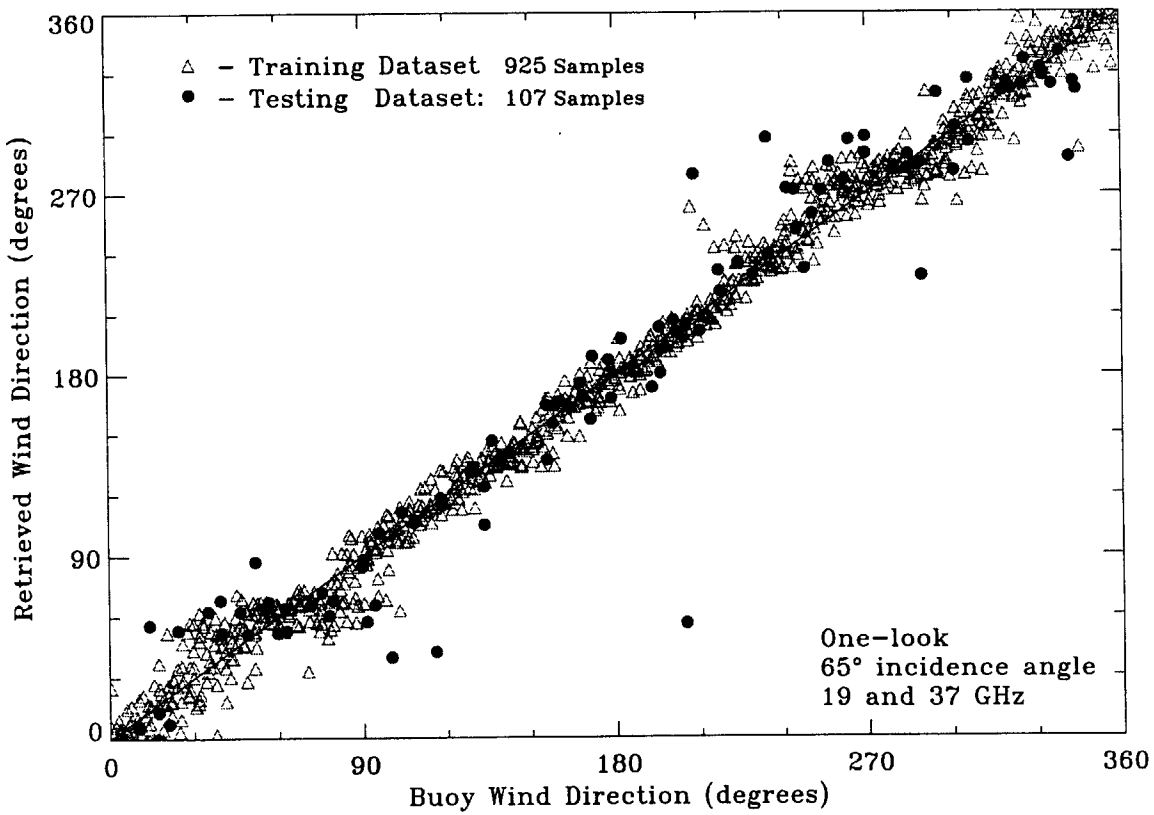
Neural Network Retrieval

- Several Neural Network Retrieval Algorithms Developed
  - Three Separate Incidence Angles
  - One-Look/Dual Frequency (Polarimetric)
  - One-Look/Single Frequency (Polarimetric)
  - Two-Look/Dual Frequency (Vertical and Horizontal Polarization Only)
  - Using All Data and Limited Data Sets
- Buoy Wind Speed and Direction Were Physical Inputs
- Each Network Was Trained with ~90% of the Appropriate Data; 10% Used for Testing

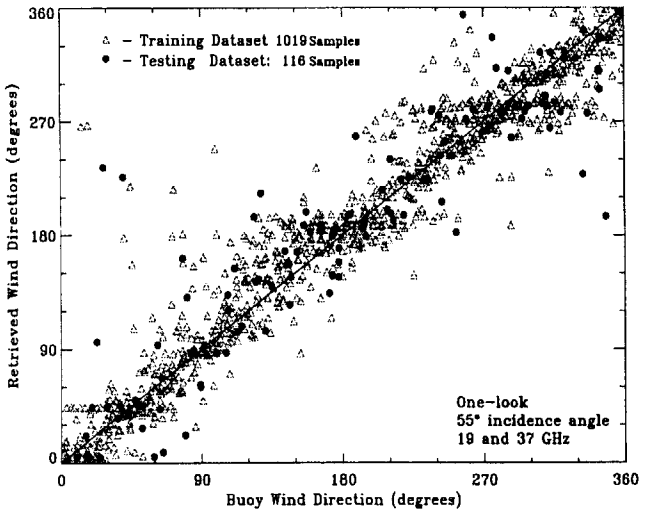
Wind Direction Retrieval
One-Look/Dual Frequency, θ=55

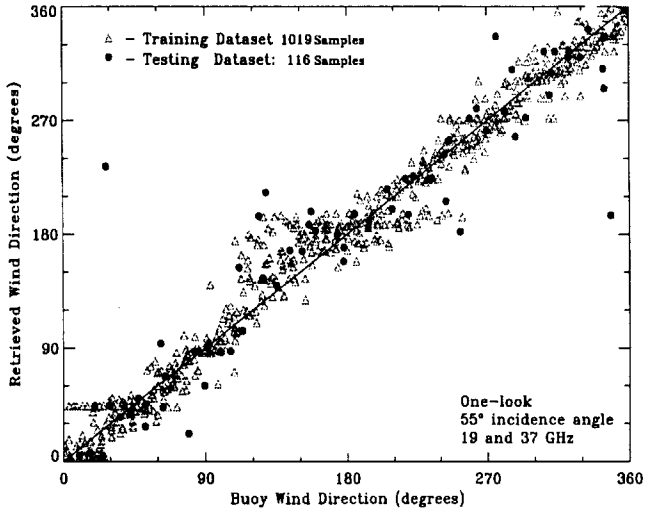


Wind Direction Retrieval
One-Look/Dual Frequency, θ=65

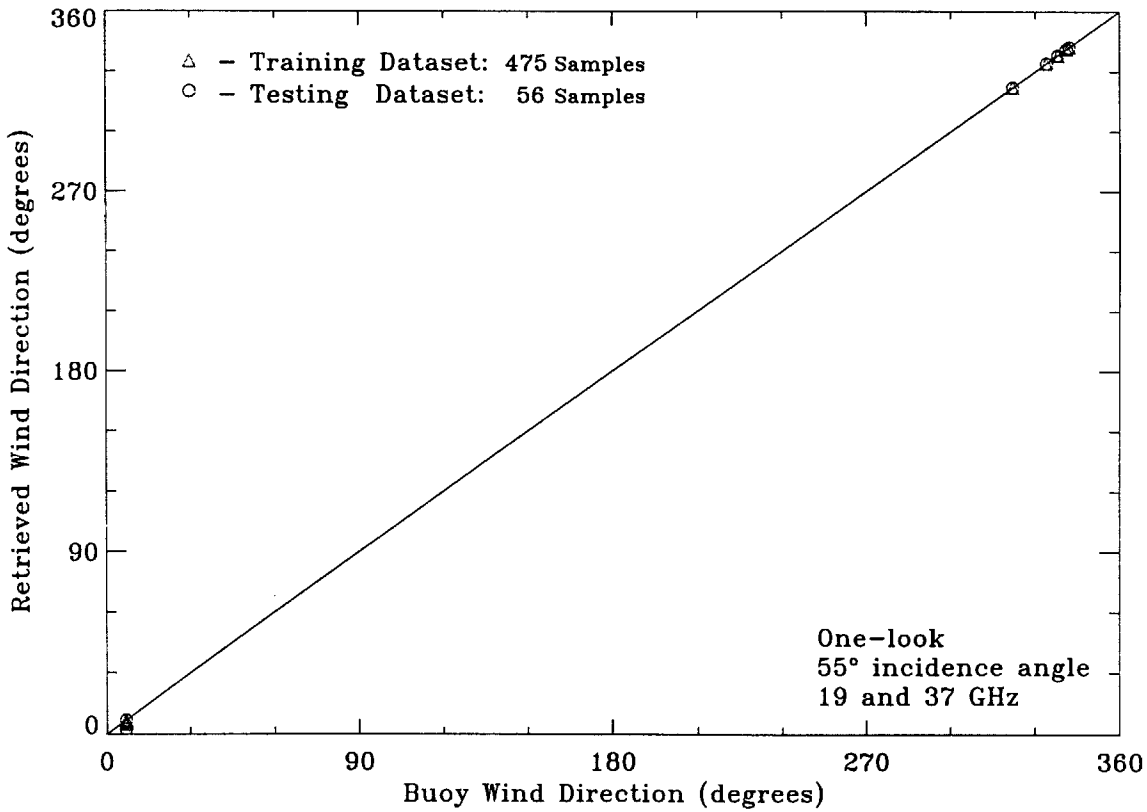


Wind Direction Retrieval One-Look/Dual Frequency, θ=55 With and Without Low Winds

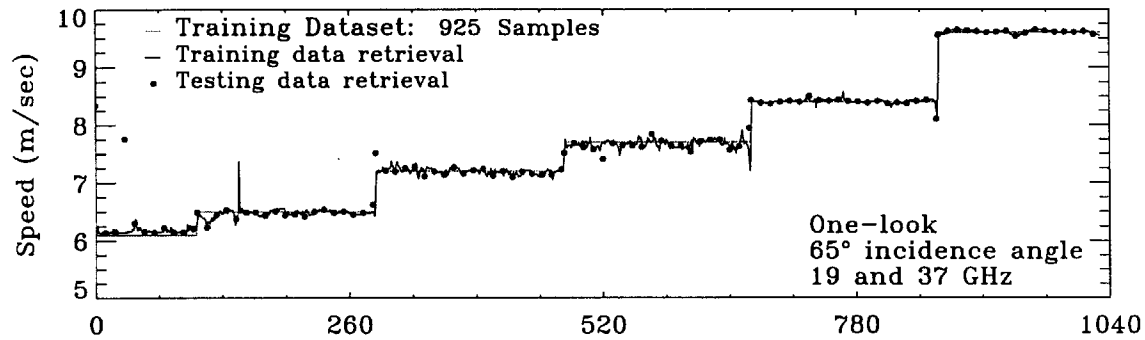


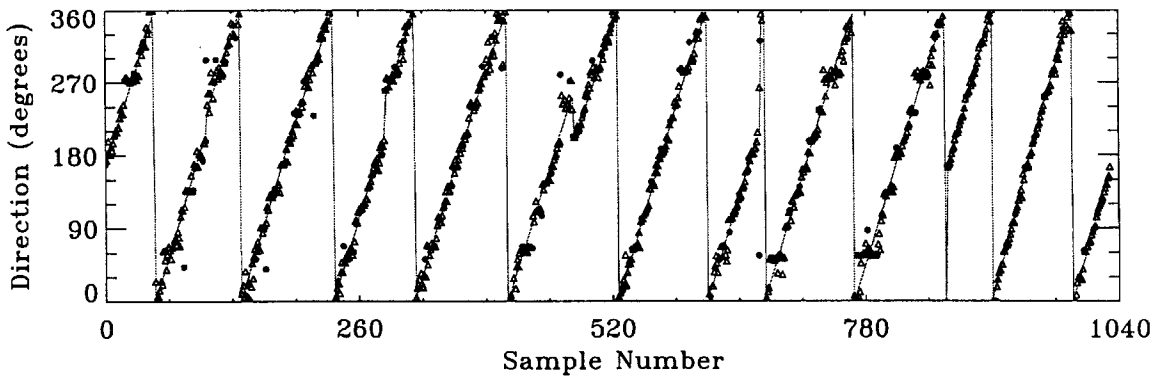


Wind Direction Retrieval
Two-Look/Dual Frequency, θ=55

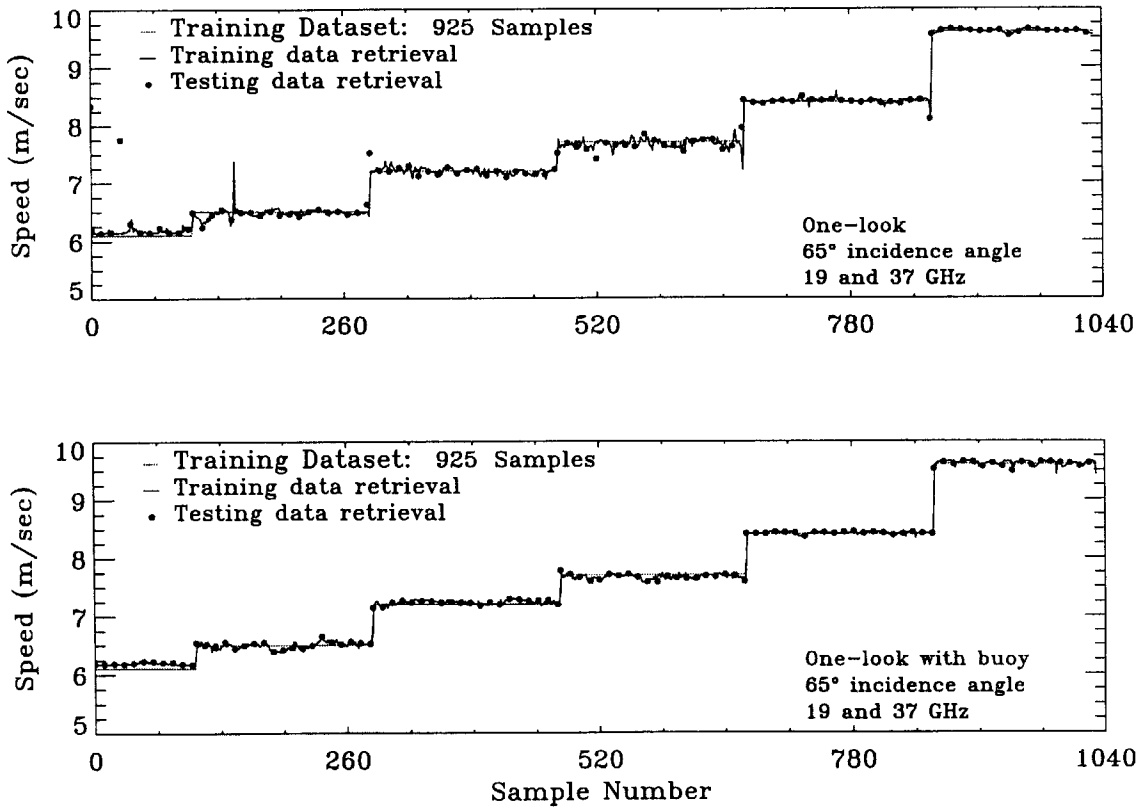


Time Series of Wind Speed and Direction Retrieval One-Look/Dual Frequency, θ=55





Time Series of Wind Speed Retrieval With and Without Buoy Data One-Look/Dual Frequency, θ=65



RMS Error of Wind Direction Retrieval

RMS Error of Direction (All Data)

Incidence Angle	Dual Freq.	19 GHz	37 GHz	Dual Freq. W/Buoy Data
45	57.7	79.4	67.6	---
55	42.3	64.7	45.2	---
65	25.5	46.1	36.1	21.6

RMS Error of Direction (No Low Winds)

Incidence Angle	Dual Freq.	19 GHz	37 GHz	Dual Freq w/ Buoy Data	Dual Freq. Select Data
45	29.9	67.1	53.1	---	38.6
55	35.9	59.1	35.2	---	12.3
65	25.5	46.1	36.1	21.6	20.2

Overall Results

- Based on the 1994 WINDRAD Dataset at 19 and 37 GHz
  - Polarimetric Radiometers Can Unambiguously Retrieve the Ocean Surface Wind Speed and Direction
  - 45, 55, and 65 Degree Incidence Angles All Provide Good Results
  - One-Look and Two-Look Schemes Both Work
  - One-Look Retrieval Requires Two Frequencies and Three Stokes Parameters
  - Two-Look Retrieval Requires Two Dual Polarization Frequencies

Recommendations

- NPOESS Sensor Should Have a Minimumof Two Polarimetric Channels
- Separate Water Vapor Channel Necessary
- Seriously Consider Including Lower Frequency Polarimetric Channel to Extend the Range of Wind Vector Retrievals
- Continue Study with Broader Data Set
  - 10 and 22 GHz In Addition to 19 and 37 GHz
  - High Winds, Low Winds, High Water Vapor and Liquid Water Atmosphere
  - Improve Robustness of Results

Follow-On Study

- Incorporate Data From 1995 Flight Experiments into FY95 Analysis
  - Includes NRL 10 and 22 GHz Data In Addition to JPL 19 and 37 GHz Data
  - Data Collections Emphasized Low Wind Conditions
- Evaluate the Utility of the 10 GHz Channel in Improving Wind Speed and Direction Retrievals, Especially in High Winds and Heavy Clouds
- Repeat Two-Look Retrieval to Include All Polarization Data
- Develop Anisotropic Surface Emission Model Incorporating Wind Direction Signature and Atmospheric Effects
- Leverage NSCAT Cal/Val and Hurricane Flights to Obtain High Wind and Storm Data

Outstanding Issues in Ocean Wind Sensing with Polarimetric Radiometers

- Polarimetric Radiometry Has Not Been Evaluated in High Winds (u>15 m/s)
- The Fourth Stokes Parameter Should be Measured and Its Utility Evaluated, Especially at High Incidence Angles
- A Better Overall Understanding of the Hydrodynamic and Electromagnetic Physics that Drive the Wind Direction Signature Is Needed
- Performance Under Adverse Weather Conditions (High Amounts of Water Vapor and Liquid Water)